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AUTHORITY

Army Signal R&D Lab ltr, 29 Jan 1963

RADIO CORPORATION OF AMERICA
RCA LABORATORIES

STUDY OF SPEECH COMPRESSION SYSTEMS
(SYLLABIC COMPRESSION TECHNIQUES)

REPORT NO. 1

CONTRACT NO: DA-36-039-SC-89191
TECHNICAL REQUIREMENT: SCL-4303 7 JUNE 1961
DA PROJECT NO: 3B31-07-001

FIRST QUARTERLY PROGRESS REPORT
15 APRIL 1962 TO 15 JULY 1962

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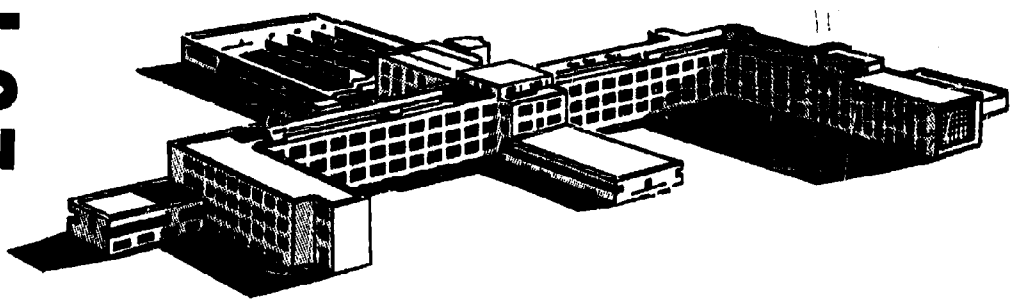
U. S. ARMY SIGNAL RESEARCH AND DEVELOPMENT LABORATORY
FORT MONMOUTH, NEW JERSEY



DAVID SARNOFF RESEARCH CENTER
PRINCETON, NEW JERSEY

STUDY OF SPEECH COMPRESSION SYSTEMS

(Syllabic Compression Techniques)

Report No. 1

Contract No.: DA-36-039 SC-89191
Technical Requirement: SCL-4303 7 June 1961
DA Project No.: 3B31-07-001

First Quarterly Progress Report 15 April 1962 to 15 July 1962.

Object: Research toward a Syllable Communication System, voice to voice and voice to print, compressed to a channel capacity of 23 bits per second and demonstration of a limited vocabulary system.

Report prepared by:

H. Belar

R. de Sobrino

E. S. Rogers

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ILLUSTRATIONS

I. PURPOSE OF THE PROJECT

Research toward a syllable communication system, voice to voice or voice to print, utilizing the phonetic typewriter developed by the RCA Laboratories and a speech synthesizer which proceeds from pre-recorded spoken syllables. Such a system when ultimately developed should allow transmission of the spoken word at an extremely low rate such as 23 bits per second calculated for a language of 2000 syllables and a normal speaking rate. A rudimentary and limited vocabulary model of such a system has been made available together with other speech processing equipment also developed at the RCA Laboratories. The purpose of this study is to make improvements in speech processing and to demonstrate the system with a limited vocabulary using an assembly of laboratory apparatus.

II. ABSTRACT

A limited and rudimentary system developed by the RCA Laboratories is the starting point of this research. The apparatus assembled can analyze and synthesize 50 syllables or words and has the resolving power and memory capacity to print-out an even larger number of words selected for this purpose, when setup for a given speaker. For 50 words the information for printout or speech synthesis is transmitted at a channel capacity of 6 bits per word.

Investigations were made using the assembled apparatus to determine performance criteria by which further progress could be measured. Tests were made using list of words other than those originally found suitable for processing by machine. One series of tests was made with a phonetically balanced list of words as used for standardized articulation testing such as PB-50 List 1. Other tests were made with the words representing the current phonetic spelling alphabet (alfa, bravo...) and also with other words chosen for their military significance.

Apparatus was assembled to investigate the usefulness of processing envelope information. Studies were made of the rate of growth, rate of decay and the duration of intra-syllable pauses. Tests were made with several thousand voicings by two speakers using indications of two quantized levels each for the growth and decay to determine useful operating point. It was found practical to definitively classify words by these characteristics and thus add to the resolving power. Work will continue in this area.

III. PUBLICATIONS, LECTURES, REPORTS and CONFERENCES

The basic work done at the RCA Laboratories is partly covered by publications made prior to work on this contract.[1,2,3,4,5,6,7,8] A lecture and demonstration[9] of such prior work was given, as previously scheduled, and at no cost to the Government, to the Acoustical Society of America Meeting in New York on 24 May 1962.

Two conferences were held with representatives of the USASRDL at the RCA Laboratories. Subjects discussed were the objectives of the contract and the means of conducting the research. These conferences are fully covered by Conference Reports dated 15 May and 13 July 1962.

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1. Harry F. Olson, Acoustical Engineering, D. Van Nostrand Company (1957).
2. Harry F. Olson and H. Belar, "Phonetic Typewriter," J. Acoust. Soc. Amer., 28, 6, 1072-1081 (November 1956).
3. Harry F. Olson and H. Belar, "Phonetic Typewriter," IRE Trans on Audio, AU-5, 4 (July-August 1957).
4. Harry F. Olson and H. Belar, "Time Compensation for Speed of Talking in Speech Recognition Machines," IRE Trans. on Audio, AU-8, 3 (May-June 1960).
5. Harry F. Olson and H. Belar, "Syllable Analyzer, Coder and Synthesizer for the Transmission of Speech," 1961 Proceedings National Aerospace Electronics Conference, NAECON, 1414 E. Third St., Dayton 3, Ohio.
6. Harry F. Olson and H. Belar, "Syllable Analyzer, Coder and Synthesizer for the Transmission of Speech," IRE Trans. on Audio, AU-10, 1 (January-February 1962).
7. Harry F. Olson and H. Belar, "A Print-out System for the Automatic Recording of the Spectral Analysis of Spoken Syllables," J. Acoust. Soc. Amer., 34, 2 (February 1962).
8. Harry F. Olson and H. Belar, "Phonetic Typewriter III," J. Acoust. Soc. Amer., 33, 11 (November 1961).
9. Harry F. Olson, H. Belar and R. deSobrino, "Speech Processing Systems," J. Acoust. Soc. Amer., 34, 5 (May 1962).

IV. FACTUAL DATA

A. Introduction

This contract, very briefly stated, requires research in speech processing, the construction of equipment to complete the chain of a syllable communications system and certain performance tests, etc. During the interval between submitting the proposal and the awarding of the contract RCA had completed construction of the syllable synthesizer and other units, thus substantially completing this portion of the work. This work was done entirely with RCA funds. Moreover, during the first month of the period covered by this report RCA personnel were engaged, also entirely at RCA expense in making the equipment ready for a demonstration to the Acoustical Society Meeting in New York as reported in the First Monthly Letter Type Report. Thus, no charges were made against this contract during the first month.

A conference was held on May 15 including the Chief of the Voice Security Branch, Mr. Martin Weinstock, and the Project Engineer, Mr. A. H. Ross as reported in the Conference Report of that date. The state of the development was reviewed. The equipment as then setup was wired to recognize 52 words by one speaker (HB) of which about 24 words could be worked by a second speaker (RdS) and 16 by the third speaker tested (GMS). The words had been chosen for purposes of demonstration and were selected from those that were found to be recognizable by the machine.

Mr. Weinstock stressed the importance of doing further work in order to increase the accuracy, the tolerance for different speakers and the vocabulary to an even greater extent than originally called for. The

feeling of RCA personnel was that, since the construction of the syllable synthesizer and other work was done at the RCA Laboratories with RCA funds in advance of the contract award, the suggested research will be possible. Specific items selected for further research were characteristics of envelopes, nonlinear amplifiers, etc. and the contractor was encouraged to explore other possibilities and submit work programs that may result in a feasibility model with greater capacity, as for example, 100 or even 200 words. The contractor was requested to add words of military significance and also to make tests with phonetically balanced word lists, etc. During the balance of the period those requests and suggestions were carried out to the extent described more fully under the follow respective headings.

B. Characteristics of Envelope

Characteristics of envelope that have been found useful in speech processing are as follows:

Growth and Decay Characteristics
Duration of Intrasyllabic Bauses
Unbalance of Bilateral Peak Envelope

Tests were made using equipment on hand which was assembled and suitably modified for this work. The processing of envelope information in various frequency bands is performed with the apparatus housed in a 82 inch relay rack. This equipment incorporates two alternative ways of quantizing growth and decay information. Provisions are made to add the result of this envelope processing to the display obtained from the phonetic typewriter[8] and the information is automatically read out with equipment

developed specially for this purpose.[7] The first method of determining the rate of growth and decay uses equipment developed in this laboratory before (not published). It determines the rate of growth or decay by the rate of change of the rectified envelope. This method is described more fully in the next section. The other method employs amplifier and relays and measures the time between reaching different levels.

C. Growth and Decay Detection by Differentiation of the Rectified Envelope

A functional schematic diagram of the Growth and Decay Detector is shown by Fig. 1, from which it can be seen that the detection of the envelope characteristics proceeds in parallel with the analysis and processing of the spoken syllable or word by elements of the phonetic typewriter. The information on growth and decay is displayed by fields in the 7th row from the bottom of the spectral memory display which is otherwise a time compensated, amplitude normalized, display of quantized information of the second derivative of the spectral response versus time. The field in column 1 was wired to indicate that the rate of growth exceeded a set threshold. The field in column 5 indicates the same for decay. The other fields in row 7 are reserved for other properties of envelope such as duration of intrasyllabic pauses. The channel corresponding to row 7, being one of the less useful channels, was omitted from the spectral analysis. Referring again to Fig. 1 the signal from the microphone is amplified and passed through a 100 cycle hp filter to prevent very low frequency components of sound (or noise) to operate the detectors. After additional amplification the signal is rectified by two rectifiers of opposite polarity to obtain a

positive and negative voltage proportional to the average amplitude of the envelope. The differentiators are connected to the output of those rectifiers. The differentiator associated with the growth detector produces a negative signal when the negative rectifier output becomes more negative because the input signal is increasing. The dc amplifier amplifies negative signals and completes a circuit when the signal exceeded a certain set threshold. A decrease in input produces a less negative voltage in the rectifier and produces a positive indication in the output of the differentiator during the interval during which the signal is decreasing. A positive signal has no effect on the dc amplifier, thus it produces an indication only when the rate of growth has exceeded a set amount. A similar determination is made during the period of decay except that the polarity of the input is reversed so that a decrease in input produces a negative indication in the output of the differentiator. A more complete circuit diagram of the growth and decay detector is given by Fig. 2.

The time-frequency analyzers, the growth and decay analysis and the coded output read-out of information all operate in real time.

The performance of the growth and decay detector was measured. A known signal of known rate of growth and decay was applied in place of the microphone output. Such a signal is obtained by reproducing RCA Laboratories Tape Record TR-89 which was made for this purpose. The results are shown by Figs. 3 and 4 which are the calibration of growth and decay detection, respectively. It can be noted from Fig. 3 that the "fast growth" is indicated when the rate of growth in the microphone output line exceeds

.009 volts per second provided a level of not less than .0007 volts is reached. Similarly it can be noted that the decay detector will indicate fast decay when the signal input decays at a rate greater than .0005 volts. As noted the performance points shown in Figs. 3 and 4 were obtained with the controls adjusted according to a schedule designated as setup 101. This adjustment was used for a number of tests described in the next section.

D. Tests Made with Growth and Decay Detector

The following tests were made with the apparatus described in the preceding section:

Setup 101

32 voicings each of 50 words PB-50 List 1, spoken by GMS.
32 voicings each of 50 words PB-50 List 1, spoken by RdS.
32 voicings each of 14 words of military significance, spoken by RdS.
32 voicings each of 26 words of the phonetic alphabet, spoken by RdS.

This total of 4480 voicings was processed by machine and the digitized analysis printed out on standardized data sheet forms for each set of 32 voicings, as shown for example by Fig. 5 for the word "box" spoken by GMS. The 32 ten letter codes typed in a column on the left of this figure represent the displays as readout by the machine. It will be noted that the 5th, 7th and 9th column have printed the identical letter and so do the 6th, 8th and 10th column. This is so, because the spectral memory has for this setup been reduced to 3 time steps which was accomplished by parallel connections of the last three steps which in effect makes the third step an extra long step. The first two letters denote the pattern in the first time step, etc. as explained before.

If all the codes that are alike are tabulated and portrayed graphically as patterns in a prescribed grid of frequency and time it is found that, as also shown by Fig. 5, there are 5 different presentations for the 32 analyses of the word "box". The pattern that appears most frequently appears 19 times, thenext frequent appears 7 times and so forth. The columns of the pattern represent time steps moving from left to right and the rows represent frequency channels with the lowest frequency channel (250 to 500 cycles per second) on the bottom. Row 7 is an exception in that column 1 in that row indicates "fast growth" and column 5 indicates "fast decay" as described before. The summary on this sheet shows the total number of times each field was operated in the 32 voicings. From this and a study of the individual codes a set of displays can be defined by an alternate higher order code which includes all or most of the codes of the first kind following procedures described elsewhere.[7,8] For instance, Alt. 1 shown requires 4 fields to always operate and 2 fields to "either" operate or not, and the balance not operated as shown by solid circles, crosses and blank squares, respectively. Compared with the known code it can be seen that the "fit" of this code is 31/32 as it will miss one display which occurs one time when it operates channel 3 relay in the second time step. Alt. 3 code which was drawn primarily for illustrations requires that the second channel in the 1st column is also not operated. Were such a code chosen and the logic corresponding to it actually wired, it would have missed 5 of the displays actually attained and the fit would be only 26/32. The graph on the lower right hand side portrays the number of new codes

that were found in successive voicings plotted on a semi-log scale. From the slope of the line drawn through the points it appears that there is approximately one new code for every double number of voicings. By extrapolation it can then be estimated that the next 32 voicings if made under the same conditions would include one new code. Taking this factor into account allows the prediction to be made by which accuracy such a code wiring would recognize the word. The shape of the curve also indicates the number of voicings that may be needed to obtain results of a required accuracy. Summing up the data presented by Fig. 5 for the word "box" spoken 32 times: It can be said that with the code Alt. 1 as shown, which fits 31 of the 32 voicings made and considering that the data is extrapolated to be 31/32 complete, the word "box" can be recognized 94% of the time; that is, provided that the code shown by Alt. 1 is mutually exclusive with respect to any other that is to be also recognized. About the word "box" it can also be noted that with the apparatus connected per setup 101 all 32 voicings indicate "fast growth" and "fast decay". When the parameters of growth alone are considered the results can be plotted for all 50 words of the PB-50 List 1 spoken by GMS in setup 101 as shown in Fig. 6. In this tabulation the words are listed in order of the frequency of occurrences of the "fast growth" indications in the 32 voicings of each word. This is not the order in which these words were spoken. They were spoken as shown on PB-50 List 1.[10] From Fig. 6 it can be seen that words beginning with "n", "s", never indicated "fast growth" and with "r" very seldom

10. American Standard for Measurement of Monosyllabic Word Intelligibility S3.2 PB-50 List 1.

(3 times in 160 voicings) whereas words beginning with "d" nearly always indicated "fast growth" (126 out of 128 times). For other sounds there is some trend but also variations. From the distribution of the indications which appears symetrical it can be assumed that the choice of threshold is in a useful range. A similar graph was made for the decay indication for the same voicings as is shown by Fig. 7. There the distribution does not appear as symetrical and an increase in sensitivity suggests itself. The sounds ending the words do not appear consistently indicated when considered out of context but when the preceding sound is included the indications make better sense. For instance a word ending in "t" preceded by a vowel like "rat", "not", "wheat", tends to show fast decay but when a semi-vowel like "n" precedes the final "t" like in "hunt", there is little tendency to indicate a "fast decay".

The results of tests using other speakers were similarly recorded and studied. Many more of those could be reported and many additional studies could be made from the data on hand, but it is deemed more desirable to test other methods for which the instrumentation has already been provided. However, one of the results is worth mentioning. When the same 50 words are spoken by a different speaker the order of frequency of occurrence of indication is not the same. Part of thi is obviously due to the speakers but some variations are due to the nature of the detection as performed. It does not distinguish between continuous and interrupted growth, etc., it is also amplitude sensitive.

A graphic presentation of the performance of the growth detector for two different speakers is shown by Fig. 8. The words are listed in the

order of frequency of occurrence for one speaker which is the same as shown in Fig. 6. The performance of the second speaker is superimposed. (The first speaker GMS was born in Trenton, the second RdS was born in Spain.)

E. Tests Using the NATO Phonetic Alphabet

A phonetic alphabet is an appropriate set of words for a limited vocabulary speech recognition machine. The present international phonetic alphabet consists of 26 words assigned to each letter of the common Roman alphabet. Two words are in a grammatical sense monosyllabic, two are three syllable words and the remaining 22 are two syllable words. Although the analyzer used was primarily designed to process one syllable words, previous work has shown that, in some cases, words of more than one syllable could be processed and recognized.

With these considerations in mind, it was decided to make the first series of tests using the phonetic alphabet by speaking the words directly into the machine without syllabicating, i.e., letting the machine analyze the whole utterance as one machine syllable. This gave good results, except in the case of two tri-syllabic words ("November" and "Uniform"). The remaining 24 words could be resolved using mutually exclusive codes in the same manner as described in the preceding section.

This test was made using the rate of growth and decay indicators.

F. Intrasyllabic Pauses

About one year ago a study was made of the duration of certain types of intrasyllabic envelope pauses, which suggested the possibility of including

this information to extend the resolving power of a speech recognition machine. At that time apparatus was designed which measured accurately ($\pm$ 1 ms) the duration of intrasyllabic pauses in sound combinations "SK", "ST", and "SP" (as in "school", "stand", "spy"). Tests conducted with four speakers (one of whom was female) and nearly two thousand voicings showed that there is a significantly longer duration in the pause preceding the "P" than in those preceding the "K" and "T". This difference was present in the case of all four speakers.

Thus, a device which detects an evelope pause and indicates whether it's duration exceeds a predetermined amount can be used to recognize the presence of the sound "SP" which otherwise with Phonetic Typewriter III may not be distinguished from "ST" or "SK".

This device could be introduced in various parts of the system; it is more convenient to extract pause duration information after the spectrum has been digitized. The duration measuring and logic circuits were developed into a unit which at the end of the reporting period was built but not yet tested.

G. Status and Summary

To review the progress and status of this contract in accordance with the Signal Corps Technical Requirements SCL-4303 and under the same headings the following can be stated:

1. Investigation

Studies were made of characteristics of the speech envelope. All the tests for which apparatus was setup have not yet been completed.

Indications of the usefulness of the approach were obtained. The work done is described in more detail in the preceding section.

2. Feasibility Model

The assembly of laboratory apparatus required to demonstrate the feasibility of the system is substantially complete. The syllable speech synthesizer, originally scheduled for construction under this contract, was completed by RCA with its own funds in advance of the contract award. Work remains to be done on minor items such as code converters and of course whatever changes that may have to be made as a result of improvements to the speech processing apparatus itself.

3. Vocabulary

The apparatus made available for this work has the capacity to store 96 words in its spelling memory with seven typing functions for each word. At present 75 words are stored in this memory. The speech synthesizer has the capacity to recall 50 words or syllables from the 50 track magnetic drum memory. It is presently charged to capacity. The analyzer and syllable memory is now setup to recognize 52 words in 2 languages, that is 46 English and 6 French words if spoken by one speaker (HB). A second speaker of different national origin (RdS) can work 24 of these words and a third speaker of still different origin (GMS, Trenton, N. J.) can work about 16 words. There is capacity left in the syllable memory for additional words, the exact number depends upon the complexity of the codes to be stored.

The vocabulary, now in the syllable memory, was originally selected from lists of most frequently occurring words, to which others were added to make demonstration sentences. Some words are left over from certain series of tests on some specific aspect of recognition. In general, the words were chosen for recognition by machine, as spoken chiefly by one speaker (HB) for whom most data was available. To increase the vocabulary of the machine mere addition to the memory capacity is not enough, however, tests can be made without actually wiring up memory circuits. The results of these tests can be made to indicate whether or not the displays obtained are mutually exclusive from those of other words, and therefore possible of recognition if so wired.

To test the operation of the apparatus with other than the original vocabulary, words were selected in conformance with directions received, namely to use words of military significance, and to use word lists that are phonetically balanced. Pending an agreement on the vocabulary to be used for the demonstration of the feasibility model preliminary selection of words were made by the contractor. One list contained 14 words of military significance which when added to some of the words now in the vocabulary would allow demonstration of such messages. For phonetically balanced lists, the PB-50 List 1 from the American Standard was chosen. Data was collected for 3 speakers with the object to establish a bench mark for the operation of the equipment and to establish a starting point from which progress could be measured.

The test with the phonetically balanced list of words made by one speaker, who voiced each of the 50 words 32 times for a total of 1600 phonations, resulted in data which was analyzed. Two successive trials were made to derive mutually exclusive codes or sets of numbers or displays which when stored in a syllable memory would recognize these words. It was found possible to specify codes or sorting procedures that would recognize with varying accuracy 49 of those 50 words as spoken by that speaker. Two words sounded alike to the machine and could not be resolved. A similar test was made with the phonetic alphabet.

4. Speakers

The first series of tests were made by the same 3 speakers that have been associated with this development before the start of this contract. Tentative plans have been made to include Signal Corps personnel.

5. Transmission Rate

The information is transmitted at present from the analyzer to the typing unit by a single connection to the respective circuit, each word having its own circuit. The transmission of 50 words to the speech synthesizer is a 6 bit code transmitted over 6 wires plus one return. Equipment for the transmission of this code into a "serial" bit code that can be transmitted over 2 wires has been partially designed and constructed.

6. Intelligibility

The accuracy of recognition by the present apparatus is better than the goal of 85% given in the technical requirement for the words chosen to suit the machine and with the machine set up for a particular speaker. It is lower than desired for other word lists such as the 50 words of PB-50 tested by a different speaker. The apparatus, however, can handle the majority of such words and should meet the specifications with a relatively small amount of editing of the word list.

V. CONCLUSIONS

From many of the tests performed with growth and decay detectors it can be concluded that information useful for the recognition of speech by machine can be extracted by such means. Setups have been provided to try other methods of detection and it is felt that these should be tested before making final conclusions.

The apparatus as now constituted more than meets the requirements for accuracy (85%) and vocabulary (40-50 words) set for the feasibility model, provided that the vocabulary is chosen to suit the machine and the machine is setup to perform with one specified speaker. It was known that mere addition to the memory was not enough to add to the vocabulary and that it would also require additional resolving power in the speech processing analyzer. A major research effort is still needed in this direction toward a full scale machine but, from the tests made, it was learned that the performance of the present apparatus was better than expected when tested with a different vocabulary and speaker. Indications are that most of the words from a limited vocabulary list, like the phonetically balanced word lists, can be handled by the machine.

VI. PROGRAM FOR THE NEXT INTERVAL

It is planned to continue tests with apparatus for the growth and decay detection by differentiation of the rectified envelope to optimize its performance. To make tests with the apparatus set up to detect the rate of growth and decay by measurement of the time interval between reaching different levels. Tests will be made with different frequency bands of the speech signal and different speakers. In order to facilitate the optimizing process some of the speakers will be recorded.

It is also intended to complete the setup of the intrasyllabic pause detector and make tests with it using the same read out facilities.

The tests will include calibration of the duration measurements and adjustments to compensate the inevitable variations in the operating and releasing times of the spectral memory relays.

Provisions have been made to make use of envelope pauses in phonemic environments other than those starting with the fricative "s".

A list furnished by USASRDL of words, some of which may be problem words by being very closely related phonetically, will be tested and the results analyzed.

A study will be undertaken of ways to recognize certain sounds out of context such as the starting sound "s" or "f" occurring as in "fee" and "see" and of incorporating this information in the display for, and recognition of, a syllable.

Other classifications of envelope characteristics by machine will be sought such as envelopes with interrupted growth and decay characteristics or envelopes with more than one maximum amplitude.

VII. IDENTIFICATION OF KEY TECHNICAL PERSONNEL

H. Belar - Project Supervisor	110-1/2 hours
R. de Sobrino - Project Engineer	199-1/2 hours
E. S. Rogers - Engineer	0

Brief descriptions of the background of key technical personnel involved in the work follows:

H. BELAR

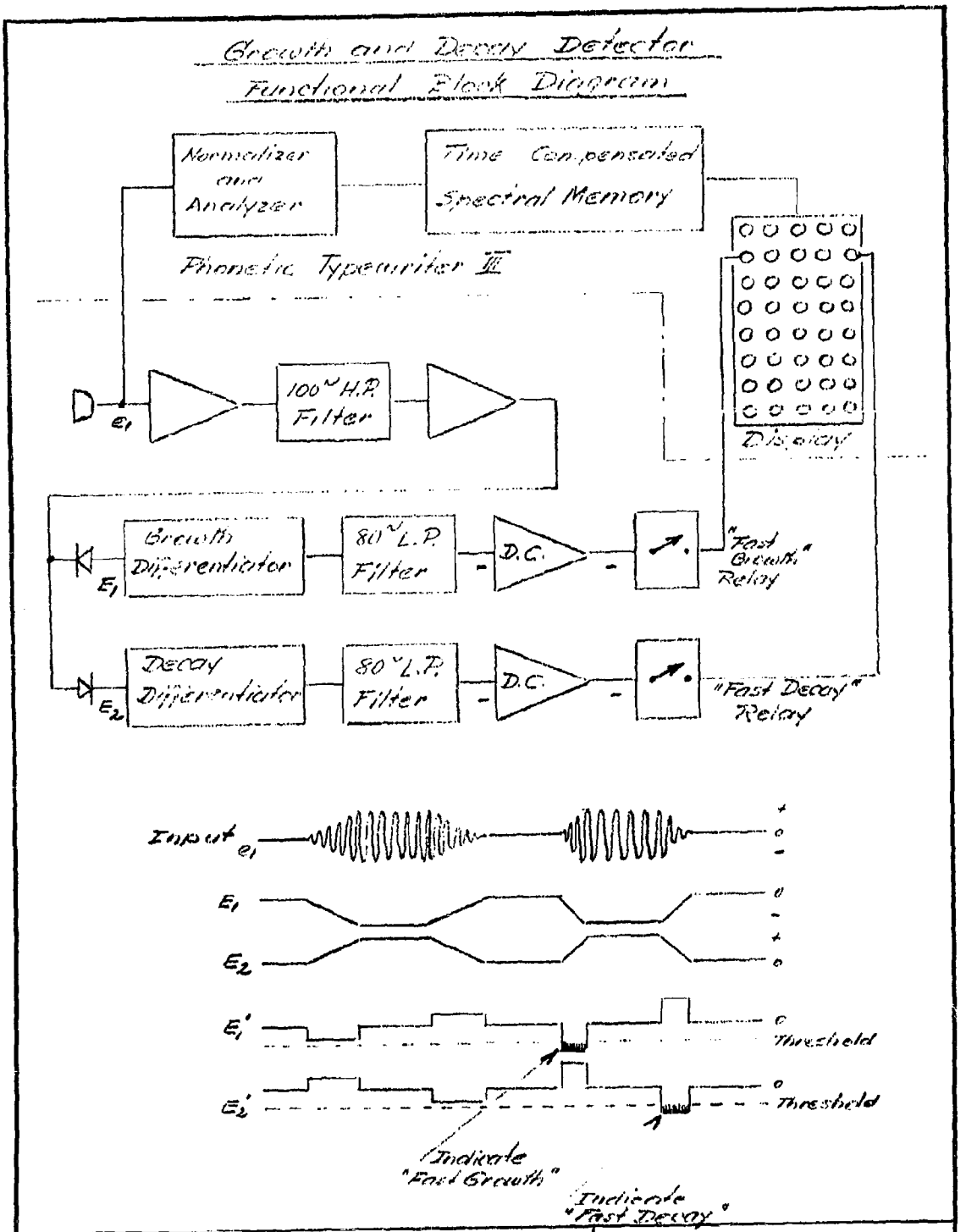
Mr. Belar is a Graduate of Naval Academy of Austria-Hungary, 1918. Mr. Belar is a Fellow in the Acoustical and Electromechanical Research Laboratory at the David Sarnoff Research Center, Princeton, N. J. and has worked for RCA for 34 years. He has made major contributions to the field of speech and music analysis and synthesis and holds 27 U. S. patents. He is the co-author of many published papers in the field of speech and music analysis and synthesis and acoustics in general.

R. de SOBRINO

Dr. de Sobrino holds the degress of EE, Spanish Navy; MEE, Brooklyn Polytech.; D. Eng. Sc., Columbia University. He has worked on communication equipment for the Spanish Navy since 1948, mainly in the equivalent of the Bureau of Naval Research in Madrid. He spent a year at Marconi Espanola, Madrid, organizing a radar testing laboratory and another year at the Instituto Nacional de Industria also in Madrid, working on the preliminary plans to install Nuclear Power Stations in Spain. In April, 1959, Dr. de Sobrino joined RCA Laboratories, Princeton, N. J., where he is currently working in the Acoustical and Electro-mechanical Research Laboratory on speech analysis.

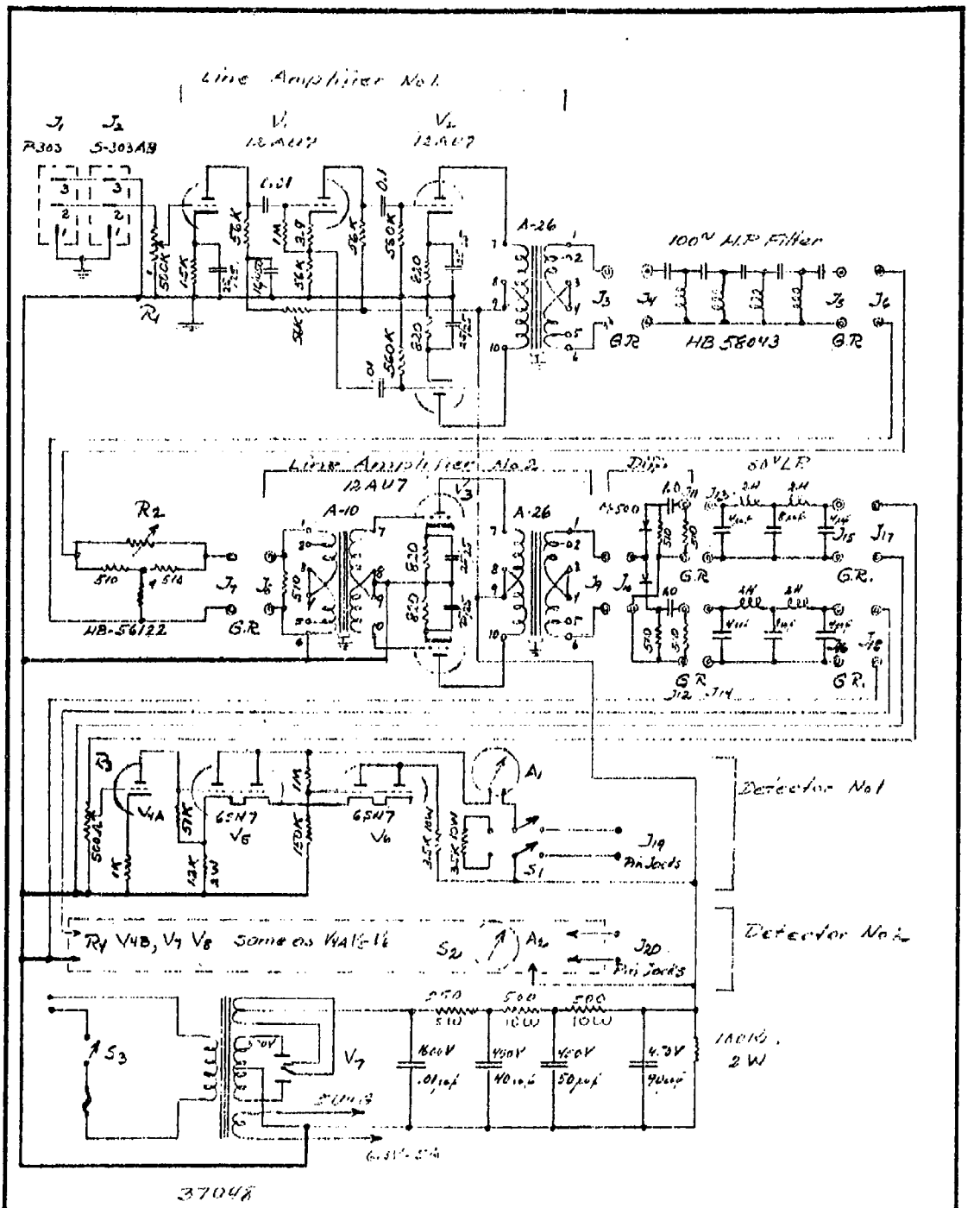
E. S. ROGERS

Mr. Rogers received the B.A. degree in Mathematics and Physics from Susquehanna University in 1942 and the M.S. degree in physics from Case Institute of Technology in 1943. From 1943 to 1945 he served with Columbia University Division of War Research, National Defense Research Council and the USN Underwater Sound Reference Laboratory engaged in Underwater Acoustics. In 1945 he joined the staff of RCA Laboratories in Princeton, N. J. His work has been primarily in the field of acoustics specializing in underwater sound, ultrasonics, speech analysis, noise reduction, and solid state electromechanical transducers. Specifically, he has spent the last four years on the articulation of speech pickup in rooms, electronic noise reducing systems for improving the intelligibility of speech in the presence of noise and formant trackers of speech.



DRAWN BY: Hubert Belcher DATE: July 30-1962 APP'D:	RADIO CORPORATION OF AMERICA RCA LABORATORIES David Sarnoff Research Center PRINCETON, N. J.	Growth and Decay Detector, Functional Block Diagram Fig. 1.

US-62068



DRAWN BY: L Belar DATE: March 28-1958 APP'D:	RADIO CORPORATION OF AMERICA RCA LABORATORIES David Sarnoff Research Center PRINCETON, N. J.	Fig. 2. Growth and Decay Detector Schematic Diagram

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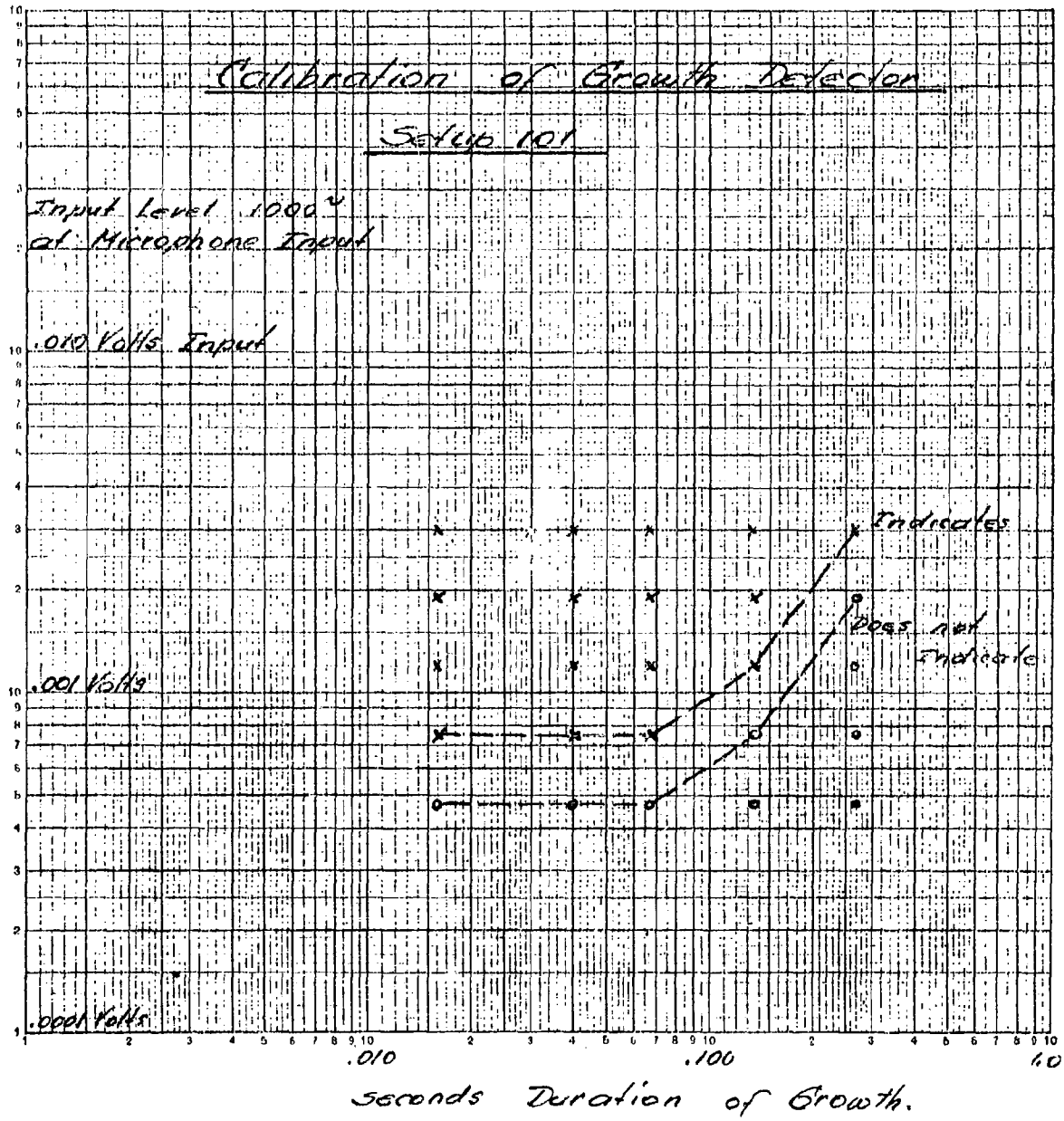
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Servo 101
Input Level .1000 V
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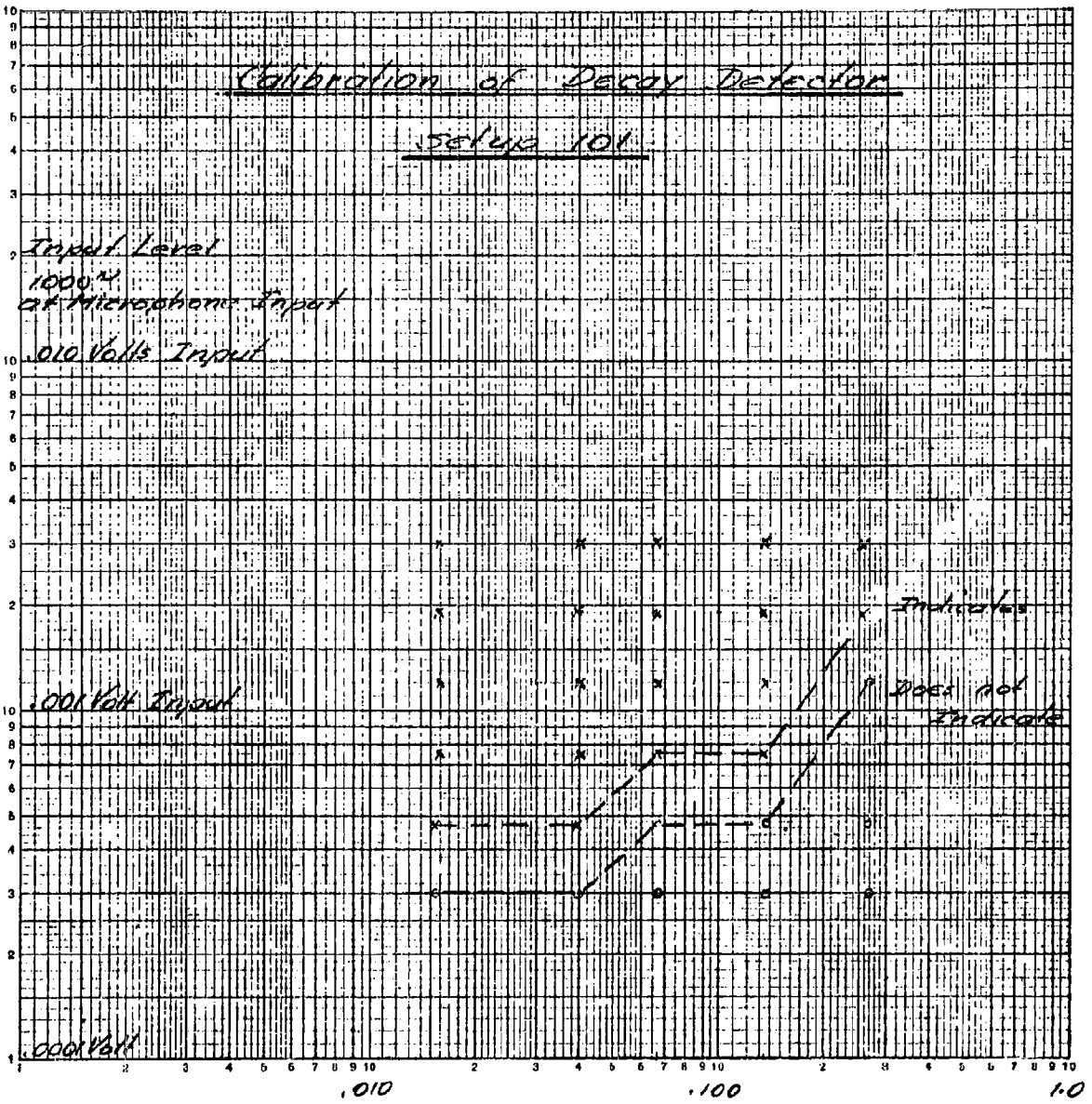
.001 Volts
.0001 Volts
Indicates
Does not
Indicate
.010
.100
1.0
Seconds Duration of Growth.

Fig. 3.


Calibration of Decay Detector
Deluxe 101
Input Level
1000 ~
at Microphone Input
.010 Volts Input
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Indicates
Does not
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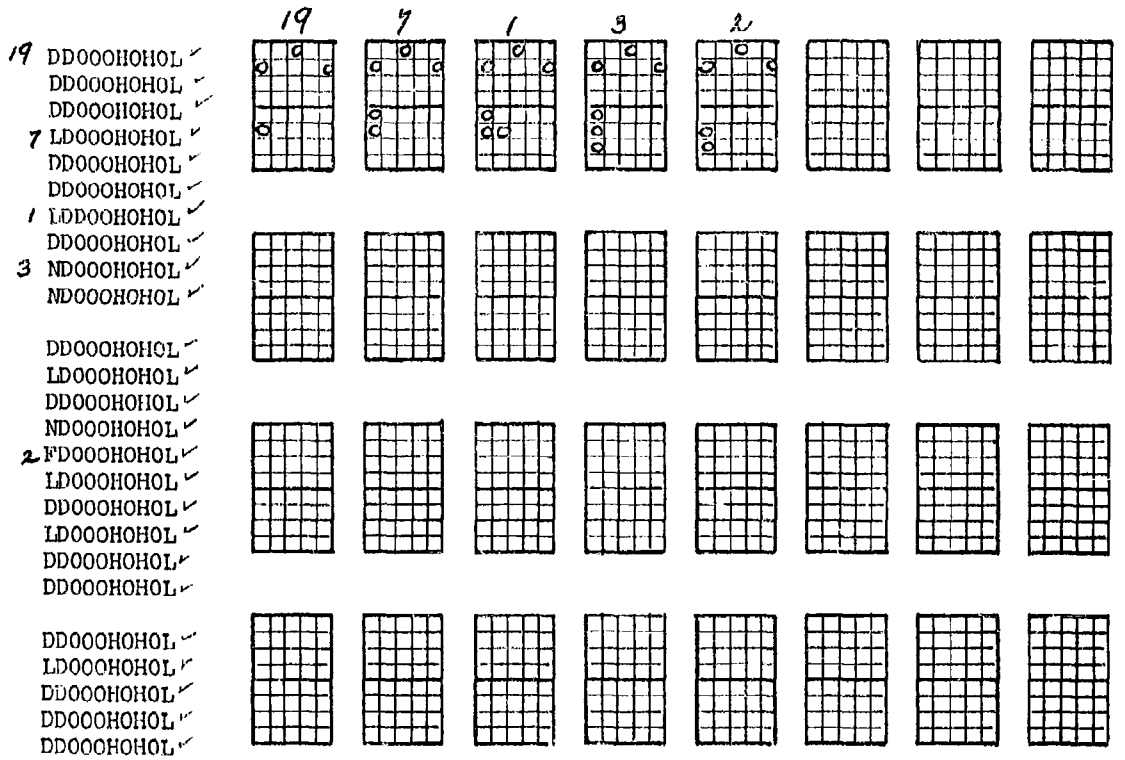
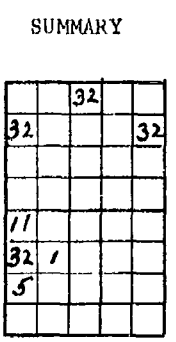
.010
.100
1.0
Seconds Duration of Decay

Fig. 4.

CODES OF THE FIRST KIND





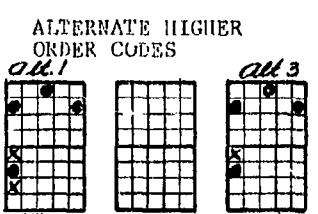


Fig.5. Codes of "Box", spoken by G.M.S.

DRAWN BY: A Belar DATE: July 31-1962 APP'D:	RADIO CORPORATION OF AMERICA RCA LABORATORIES David Sarnoff Research Center PRINCETON, N. J.	SETUP: 101 SPEAKER: GMS WORD: BOX 7/2/62

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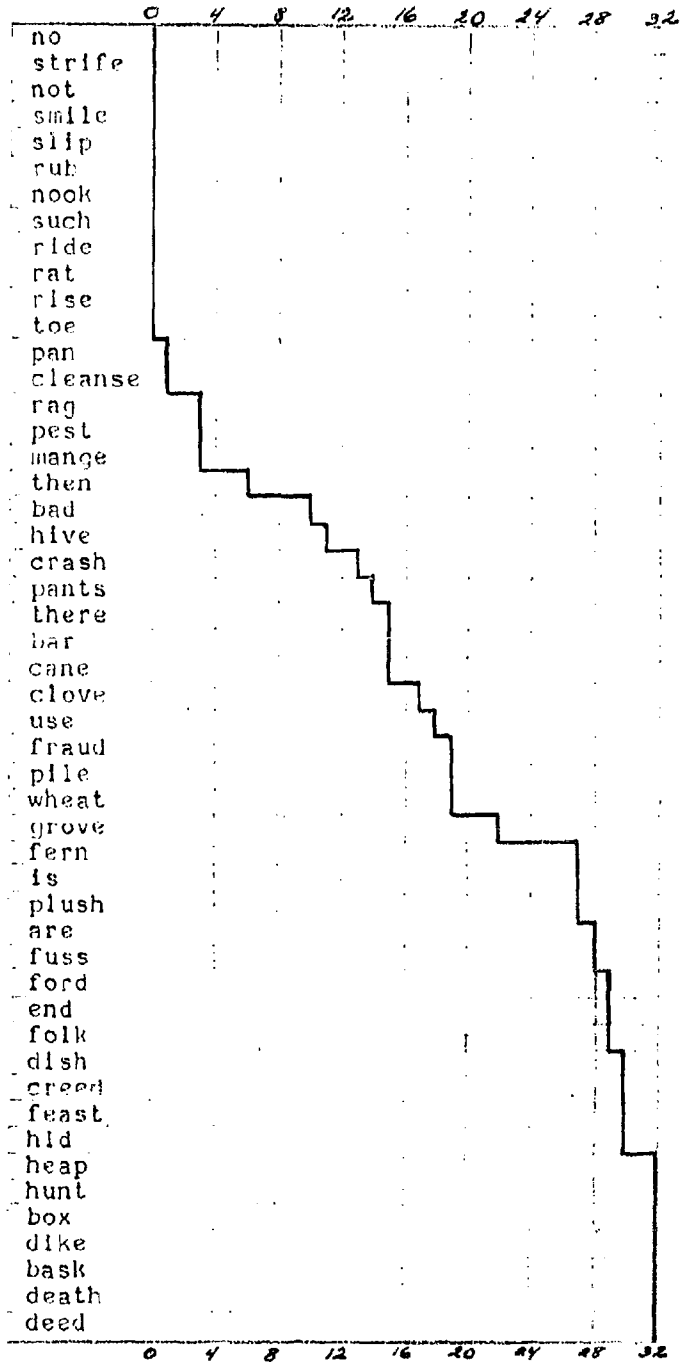

Fig. 6

Growth Detector

PB-50 List 1, spoken by G.M.S. 32 times each word, plotted in order of frequency of occurence of "Fast Growth" Indication

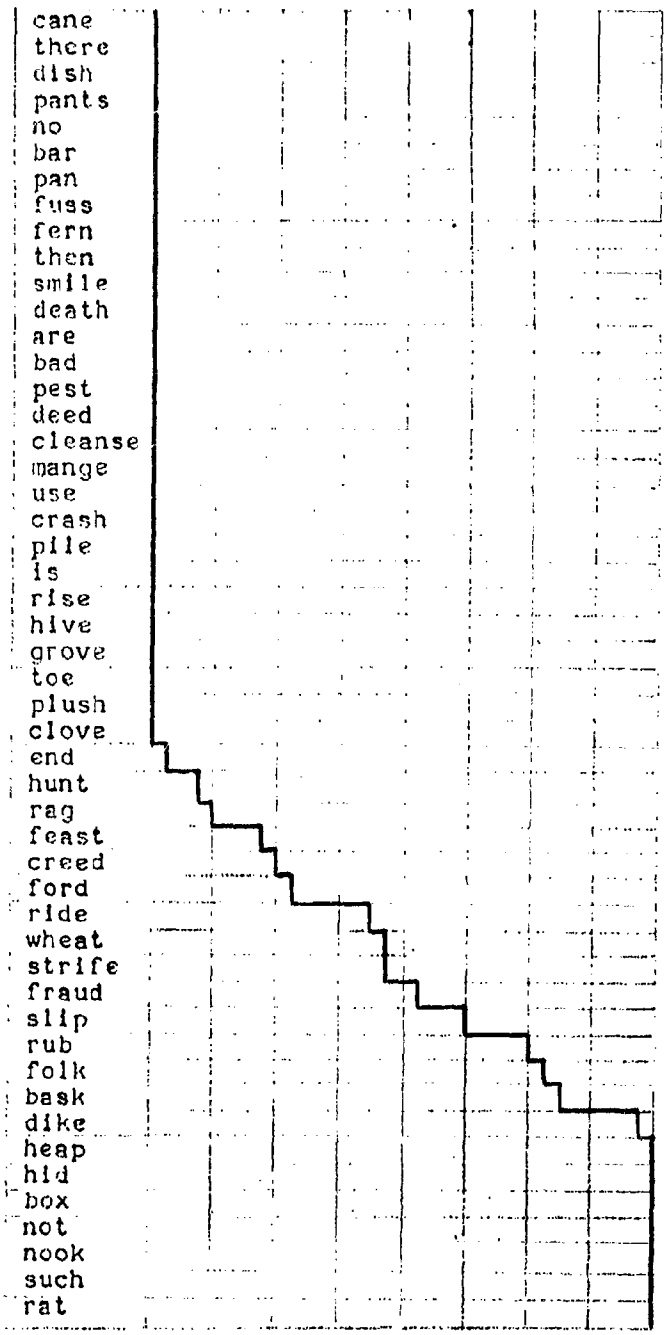

Fig. 7.

Decay Detector

PB-50 List 1 spoken by G.M.S. 32 times each word, plotted in order of frequency of Occurence of "Fast Decay" Indication.

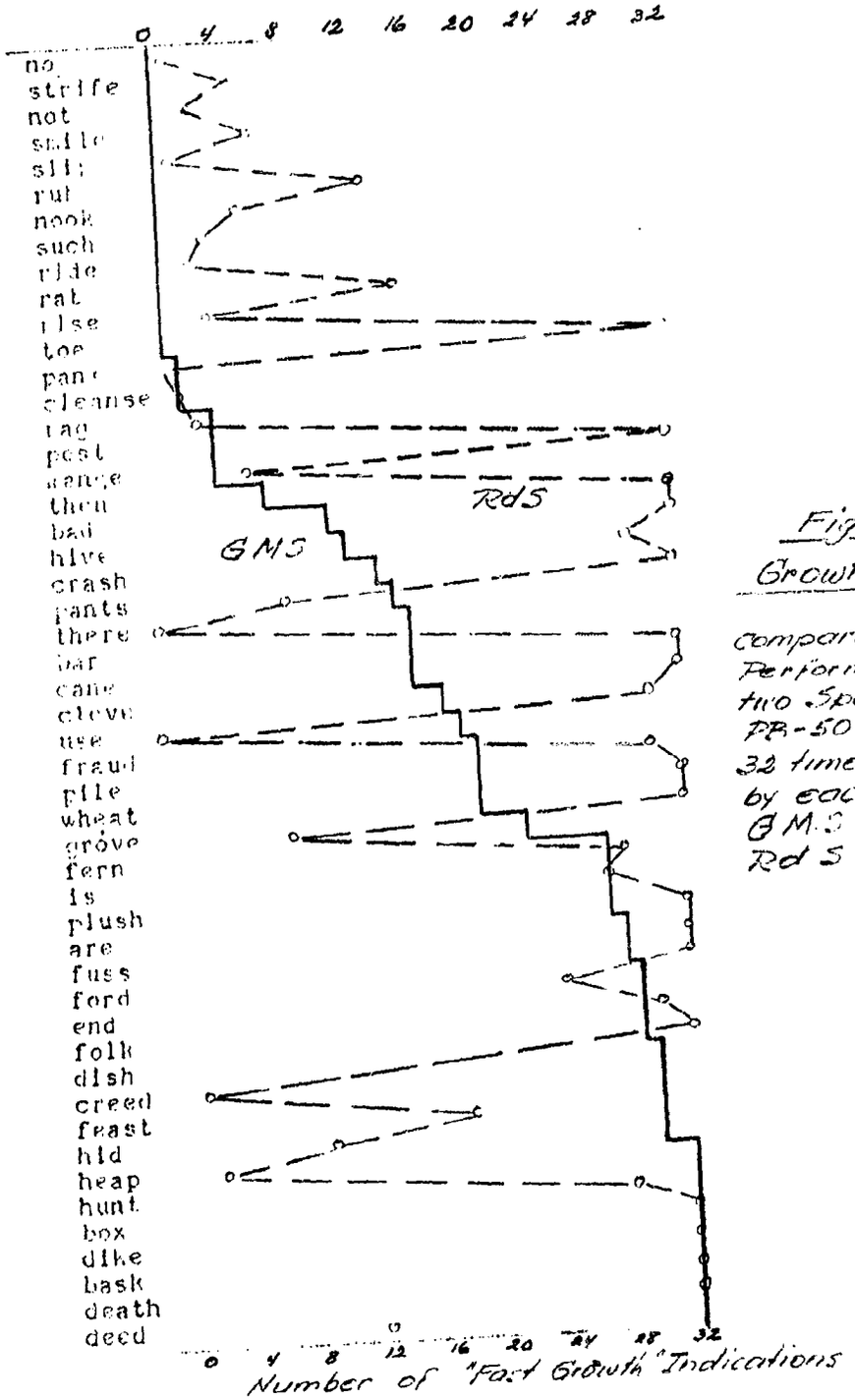

Fig. 8.
Growth Detector

Comparison of performance with two speakers. PB-50 Lists 1, spoken 32 times each word by each speaker, GMS Setup 101 Rd 5 Setup 101.

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A limited and rudimentary system developed by the RCA Labs is the starting point of this research. The apparatus, when setup for a given speaker, can analyze, synthesize, and transmit 50 syllables or words at a channel capacity of 6 bits per word.

Tests were made using the RCA apparatus and performance data were obtained with, phonetically balanced word lists, the phonetic alphabet, and with list of words of military significance. Studies were made of the rate of growth, rate of decay and the duration of intrasyllabic pauses. Tests were made with several thousand voicings by 2 speakers. It was found practical to definitively classify words by these characteristics and thus add to the resolving power.

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